REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	June 1992	Final Report

4. TITLE AND SUBTITLE

Ionospheric Predictions Undertaken as Part of a Study of O and M Radar Performance

5. FUNDING NUMBERS

F6170892W0350

6. AUTHOR(S)

Prof Tudor Jones

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

University of Leicester
Department of Physics
University Road
Leicester LE1 7RH, England

8. PERFORMING ORGANIZATION REPORT NUMBER

SPC-92-4011

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

EOARD
PSC 802 BOX 14
FPO AE 09499-0200

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

SPC-92-4011

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The aim of the study was to examine the influence of ionospheric propagation conditions on the performance of ROTHR type radar installations. Possible sites for locating the radars was specified as was the viewing area of interest. The final objective of the study was to determine the comparative sensitivity over the full beam width for ranges between 1000 and 3000 km from the radars. The ionospheric models were to represent conditions of low, medium and high sun spot numbers and include the normal diurnal and seasonal variations of the ionosphere. After discussions with the sponsors, the parameters required to specify the system performance were identified and the program divided into two work packages which were to be undertaken at Leicester and RSRE respectively. The work at Leicester involved the calculation of the ionospheric propagation conditions and of the expected signal strength and mode structure. A number of transmitter sites were considered by sponsors and they specified that the initial studies were to be made assuming the radars were located at Grand Fork and Bakersfield. The initial calculations for these two sites were presented at a meeting with the sponsors on 25/26 September 1991. A draft report was produced in October and the final report on the joint work, which included four specified sites and full details of the expected coverage from these sites was submitted to the sponsors by RSRE at the end of 1991.

14. SUBJECT TERMS

15. NUMBER OF PAGES

6

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19, SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

Final Report: **On Ionospheric predictions undertaken as part of a study of O and M radar performance (Ref:SPC-92-4011).**

1. Introduction.

The aim of the study was to examine the influence of ionospheric propagation conditions on the performance of ROTHR type radar installations. Possible sites for locating the radars were specified as was the viewing area of interest. The final objective of the study was to determine the comparative sensitivity over the full beam width for ranges between 1000 and 3000 km from the radars. The ionospheric models were to represent conditions of low, medium and high sun spot numbers and include the normal diurnal and seasonal variations of the ionosphere. After discussions with the sponsors, the parameters required to specify the system performance were identified and the programme divided into two work packages which were to be undertaken at Leicester and RSRE respectively.

The work at Leicester involved the calculation of the ionospheric propagation conditions and of the expected signal strength and mode structure. A number of transmitter sites were considered by the sponsors and they specified that the initial studies were to be made assuming the radars were located at Grand Fork and Bakersfield. The initial calculations for these two sites were presented at a meeting with the sponsors on 25/26 September 1991. A draft report was produced in October and the final report on the joint work, which included four specified sites and full details of the expected coverage from these sites was submitted to the sponsors by RSRE at the end of 1991.

2. Initial Investigations.

Coordinates of the notional target points at the required bearings and ranges for the two sites were supplied to Leicester by RSRE. For each transmitter site there were three bearings, these being the boresight and ± 30° on either side of the boresight. For each boresight five ranges were specified, ie. 1000, 1500, 2000, 2100 and 3000 km. The frequencies of interest were also specified. This information enabled the propagation parameters to be calculated at Leicester using the IONCAP, ionospheric prediction programme. This programme is extensively employed by many agencies for evaluating HF propagation conditions. In the present study, the conditions were calculated for the sites and ranges specified by the sponsor as indicated above.

For each nominal target point, calculations were made as follows:-

(a) At four hourly intervals throughout the day (ie. 00, 04, 05.....20,24 LT).

(b) For three sun spot number values (10,75,150).

(c) For the months June, September and December

(d) Frequencies of 5, 6, 8, 10, 12, 16, 20, 24, 28 MHz inclusive.

Isotropic models of the antenna gain patterns were employed throughout so that the ionospheric loss could be evaluated. Later, realistic models of antenna gains were applied to the data by RSRE for each frequency and elevation angle. Some changes were made to the IONCAP programme so that only those parameters required by RSRE to determine the system performance were printed out.

3. Discussion of the initial investigations.

A meeting was held at Leicester on 17 September to discuss the incorporation of the predicted field strengths into the Radar Equation calculation. Attention was given to the noise models employed in the prediction programme since the ambient noise level greatly influences the signal to noise ratios that can be achieved with a given radar system. It was agreed that the CCIR (CCIR report 322-2) models employed in the prediction calculations were acceptable and two noise levels 'Remote' (-164 db) and 'Rural' (-148 db) were thought to be representative of the sites under consideration.

In order to determine the ray paths to the target areas, additional calculations were undertaken using a 'ray tracing' analysis. This was the Jones 3D ray tracing package which is extensively employed for modelling studies of this kind. In view of the complexity of this analysis, the calculations were restricted to the azimuths and ranges of primary interest (ie. the boresight site and ranges between 1000 to 3000 km). The ray tracing study confirmed the mode type and elevation angles necessary for the required coverage. The calculations also confirmed the MUF and LUF expected for different times of day, season and sun spot number. Ray plots were generated for all frequencies and an example of the graphical output obtained is reproduced as figure 1.

These initial results were presented at a meeting held at Leicester on 26 September and were very well received. At this meeting two additional transmitter sites were

added to those originally specified. These were Norfolk, Virginia, and Kingsville, Texas.

Summary of Prediction effort

For each of the transmitter sites 3 bearings and 5 ranges were specified, ie. 15 nominal target points for each site. Calculations were required for all of these at four hourly intervals (ie. 6 times), for 3 sun spot numbers and for 3 months (seasons). This produced an output of 540 sides on the lazer printer. Each output page gives the **propagation mode, elevation angle** and **transmission loss** for each of the 9 frequencies and for the 4-hourly intervals. An example of an output page is reproduced as figure 2.

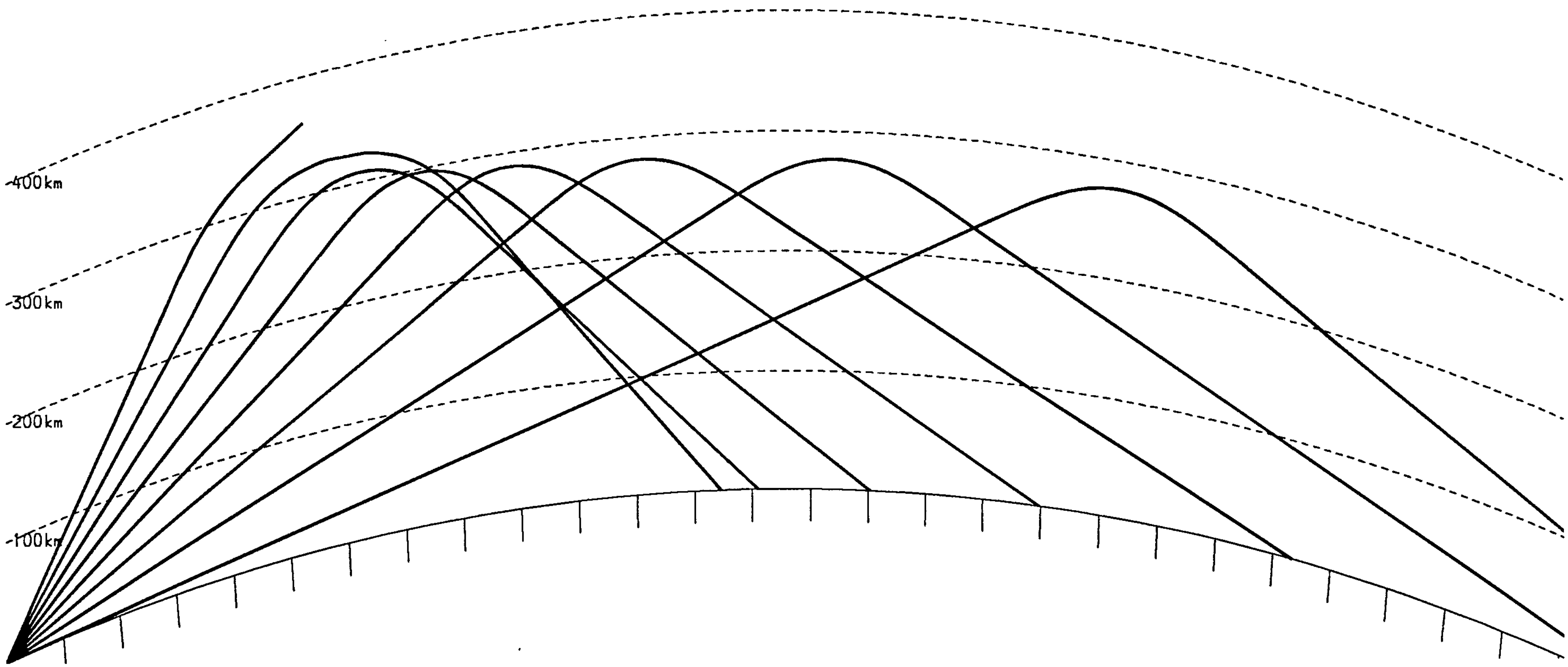
In addition, predictions of absorption loss, comprising 10 pages each were obtained for:-

Site 1	Boresight	range 2000 km	'remote' noise model
Site 1	Boresight	range 1500 km	'remote' noise model
Site 1	Boresight	range 2000 km	'rural' noise model
Site 1	Boresight	range 1500 km	'rural' noise model

ie: in all 40 pages of output. A specimen page of this output is reproduced in figure 3. In addition, several short runs were made for comparison and discussion purposes.

All the data were produced on schedule and supplied to RSRE in the agreed format. The data were employed by RSRE for determining the system performance by means of their radar cross section analysis technique. A special section on the prediction calculations was written for the final report and this was duly included. (see Appendix 1 and 3 of the Final Report). Extensive discussions took place with RSRE during the analysis and in the drafting of the final report which was delivered to the sponsor at the end of 1991. All computer output was supplied to RSRE who still hold these data. All the data generated at Leicester are included in the analysis presented in the Final Report.

**** site 1, bearing 2, June, sun spot no 75, local noon ****



Frequency is 12.00MHz, Azimuth is 111.00, Mode is ORDINARY

100.00km between Tick Marks along earth surface

the ionospheric parameters used are:-
7.10 341.30 50.00 1.00 0.00 0.00 0.00 0.00

FIGURE 1

SITE1 BEARING 2 RANGE 3000

transmitter	36.00 N	119.00 W
target point	23.00 N	92.00 W

year	1992
month	JUN
sunspot number	10.

bearing	111.7
great circle distance km	2971.

UT	MUF												
4.0	17.3	5.0	6.0	8.0	10.0	12.0	16.0	20.0	24.0	28.0	0.0	0.0	FREQ
	1F2	1F2	1F2	1F2	1F2	1F2	1F2	1F2	1F2	1F2	-	-	MODE
	6.9	2.4	2.2	2.2	2.4	2.7	4.3	6.9	6.9	6.9	-	-	ANGLE
	145.	137.	137.	139.	138.	136.	138.	162.	208.	269.	-	-	LOSS

UT	MUF												
8.0	11.2	5.0	6.0	8.0	10.0	12.0	16.0	20.0	24.0	28.0	0.0	0.0	FREQ
	1F2	1F2	1F2	1F2	1F2	1F2	2ES	2ES	1F2	1F2	-	-	MODE
	7.5	2.8	2.9	3.4	4.5	7.5	5.0	5.0	7.5	7.5	-	-	ANGLE
	139.	130.	131.	133.	134.	145.	172.	205.	298.	299.	-	-	LOSS

UT	MUF												
12.0	12.0	5.0	6.0	8.0	10.0	12.0	16.0	20.0	24.0	28.0	0.0	0.0	FREQ
	1F2	2 E	2F2	1F2	1F2	1F2	1F2	1F2	1F2	1F2	-	-	MODE
	7.5	4.4	15.9	3.4	3.7	7.5	7.5	7.5	7.5	7.5	-	-	ANGLE
	144.	143.	145.	138.	136.	144.	172.	222.	281.	310.	-	-	LOSS

UT	MUF												
16.0	18.2	5.0	6.0	8.0	10.0	12.0	16.0	20.0	24.0	28.0	0.0	0.0	FREQ
	1F2	2ES	2ES	2 E	2 E	2 E	1F2	1F2	1F2	1F2	-	-	MODE
	8.3	5.0	5.0	4.1	4.4	4.9	6.9	8.3	8.3	8.3	-	-	ANGLE
	149.	202.	190.	169.	159.	157.	144.	161.	209.	277.	-	-	LOSS

UT	MUF												
20.0	19.2	5.0	6.0	8.0	10.0	12.0	16.0	20.0	24.0	28.0	0.0	0.0	FREQ
	1F2	2ES	2ES	2 E	2F2	2F2	1F2	1F2	1F2	1F2	-	-	MODE
	9.6	5.0	5.0	3.9	22.9	20.7	9.0	9.6	9.6	9.6	-	-	ANGLE
	152.	254.	230.	198.	167.	162.	147.	154.	180.	226.	-	-	LOSS

UT	MUF												
24.0	21.3	5.0	6.0	8.0	10.0	12.0	16.0	20.0	24.0	28.0	0.0	0.0	FREQ
	1F2	2 E	2 E	2 E	2F2	1F2	1F2	1F2	1F2	1F2	-	-	MODE
	7.2	4.0	4.2	4.6	14.3	2.6	2.6	4.2	7.2	7.2	-	-	ANGLE
	149.	163.	156.	151.	150.	142.	140.	142.	163.	200.	-	-	LOSS

FIGURE 2

FIGURE 3

```
1IONOSPHERIC COMMUNICATIONS ANALYSIS AND PREDICTION PROGRAM - IONCAP   VERSION 85.04

          1         2         3         4         5         6         7         8
 12345678901234567890123456789012345678901234567890123456789012345678901234567890

 METHOD       20    1
 COMMENT             2         3         4         5         6         7
 COMMENT    123456789012345678901234567890123456789012345678901234567890123456789
 CIRCUIT     3600N    11900W     3000N    10500W        0
 LABEL
 SYSTEM     500.0   -3. 2.00   90. 10.0 10.00.850
 MONTH       1992     3    6     9    12
 SUNSPOT      75.
 TIME           4    24    4     0
 FREQUENCY   5.00 6.00 8.0010.0012.0016.0020.0024.0028.00
 ANTENNA        1    1220.00.0100   10.             0.00                      30.00    1
 ANTENNA        2    12 0.00.0100   10.             0.00                      30.00    1
 EXECUTE        0
 COMMENT             2         3         4         5         6         7
 COMMENT    123456789012345678901234567890123456789012345678901234567890123456789
 QUIT
```

```
1                                   METHOD 20   IONCAP 85.04   PAGE   1

           MAR       1992           SSN =   75.
                                                 AZIMUTHS             N. MI.       KM
  36.00 N   119.00 W - 30.00 N   105.00 W    113.11   300.77         790.5     1463.9
                                    MINIMUM ANGLE    2.0  DEGREES
  ITS- 1 ANTENNA PACKAGE
  XMTR 1.0 TO 30.0 CONSTANT GAIN          H  0.00   L  0.00   A    0.0  OFF AZ  20.0
  RCVR 1.0 TO 30.0 CONSTANT GAIN          H  0.00   L  0.00   A    0.0  OFF AZ   0.0
  POWER = 500.000 KW   3 MHZ NOISE = -148.0 DBW    REQ. REL = .90  REQ. SNR = 10.0
  MULTIPATH POWER TOLERANCE = 10.0 DB   MULTIPATH DELAY TOLERANCE =   0.850 MS
```

UT	MUF												
4.0	11.7	5.0	6.0	8.0	10.0	12.0	16.0	20.0	24.0	28.0	0.0	0.0	FREQ
	1F2	1F2	1F2	1F2	1F2	1F2	1F2	1F2	1F2	1F2	-	-	MODE
	22.0	16.1	16.1	16.6	17.9	24.0	24.0	24.0	24.0	24.0	-	-	ANGLE
	5.5	5.3	5.3	5.3	5.4	5.7	5.7	5.7	5.7	5.7	-	-	DELAY
	356.	263.	263.	271.	291.	390.	390.	390.	390.	390.	-	-	V HITE
	0.50	1.00	0.99	0.93	0.75	0.45	0.02	0.00	0.00	0.00	-	-	F DAYS
	111.	102.	102.	103.	106.	114.	143.	192.	219.	221.	-	-	LOSS
	79.	78.	78.	79.	79.	72.	45.	-2.	-27.	-27.	-	-	DBU
	-48	-42	-44	-45	-47	-56	-86	-134	-162	-163	-	-	S DBW
	-160	-148	-150	-154	-157	-161	-166	-170	-172	-174	-	-	N DBW
	111.	105.	106.	108.	109.	105.	81.	36.	11.	11.	-	-	SNR
	-83.	-87.	-89.	-90.	-90.	-72.	-45.	0.	6.	6.	-	-	RPWRG
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.55	0.59	-	-	REL
	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-	MPROB
	1.00	1.00	1.00	1.00	1.00	0.99	0.91	0.49	0.30	0.31	-	-	S PRB
	17.	1.	2.	3.	7.	21.	25.	25.	1.	1.	-	-	SIG LW
	8.	5.	5.	5.	5.	10.	25.	25.	15.	4.	-	-	SIG UP
	79.	78.	78.	79.	79.	72.	45.	41.	41.	41.	-	-	VHFDBU
	17.	1.	2.	3.	7.	21.	25.	6.	6.	6.	-	-	VHF LW
	8.	5.	5.	5.	5.	10.	25.	8.	8.	8.	-	-	VHF UP
	F	F2	F2	F2	F2	F	F	F	F	F	-	-	VHFMOD
	19.	8.	7.	8.	10.	22.	26.	26.	7.	7.	-	-	SNR LW
	11.	10.	10.	9.	9.	12.	26.	26.	17.	10.	-	-	SNR UP
8.0	9.7	5.0	6.0	8.0	10.0	12.0	16.0	20.0	24.0	28.0	0.0	0.0	FREQ
	1F2	1F2	1F2	1F2	1F2	1F2	1F2	1F2	1F2	1F2	-	-	MODE
	23.6	17.2	17.5	18.9	25.0	25.0	25.0	25.0	25.0	25.0	-	-	ANGLE
	5.6	5.3	5.3	5.4	5.7	5.7	5.7	5.7	5.7	5.7	-	-	DELAY
	382.	280.	285.	306.	408.	408.	408.	408.	408.	408.	-	-	V HITE
	0.50	1.00	0.98	0.83	0.42	0.08	0.00	0.00	0.00	0.00	-	-	F DAYS
	109.	100.	101.	103.	112.	128.	184.	214.	215.	217.	-	-	LOSS
	79.	79.	80.	79.	72.	58.	4.	-24.	-24.	-24.	-	-	DBU
	-47	-41	-42	-44	-54	-70	-127	-156	-158	-159	-	-	S DBW
	-157	-145	-148	-153	-158	-162	-167	-170	-172	-174	-	-	N DBW
	110.	104.	105.	108.	104.	92.	40.	14.	15.	15.	-	-	SNR
	-84.	-87.	-88.	-90.	-75.	-56.	-5.	3.	2.	2.	-	-	RPWRG
	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.76	0.80	0.83	-	-	REL
	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-	MPROB
	1.00	1.00	1.00	1.00	1.00	0.96	0.55	0.37	0.39	0.41	-	-	S PRB
	15.	1.	2.	5.	18.	25.	25.	1.	1.	1.	-	-	SIG LW